§15. Development of Microwave Imaging Technology

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Microwave imaging diagnosis[1,2] was proposed for three-dimensional observation of the local electron density and temperature in magnetically confined plasma. Microwave Imaging Reflectometry[3] (MIR) and Electron Cyclotron Emission Imaging (ECEI) became a combined diagnosis system in Large Helical Device (LHD). The system development brings new findings to the plasma physics. MIR system needs to know both position and shape of a cut-off surface (reflection surface) on which density fluctuations are visualized as an image. The surface can be approximately estimated by Thomson scattering diagnosis in the present setup. It is better to use a direct method of precisely measuring the surface shape and position.

A new pulsed-wave CT system was designed as a two-dimensional reflectometer for a metal or dielectric object. A schematic view of the system is shown in figure 1. The pulse generator outputs a short pulse with the pulse width of 300 psec. The pulse wave is supplied to an transmitter of a log spiral antenna. The incident wave is circularly polarized. Dispersion property of the antenna increases the pulse width to several nano-seconds. The incident pulse drives a resonance current on the surface of the object. The object emits a resonance wave as a dipole antenna. The wavelength is twice as long as the object length. Superposition of the incident wave and resonance waves are received on a receiver of dipole antenna. The received wave is recorded by a sampling scope of LeCroy WE100H. The resonance waveform is extracted from the wave superposition.

The log spiral antenna was made for a short-pulse transmitter. The pattern of the antenna element is shown in figure 2. The antenna transmits a circularly polarized wave with the bandwidth of 0.5 to 2.5 GHz. The antenna element is terminated to ground at the end in order to eliminate a reflection wave. A dipole antenna is used as a receiver. It receives the resonance wave as the linearly polarized wave.

The spectrum of the resonance wave is analyzed by the Fourier transform. The spectrum is shown in figure 3. When the object length is 15 cm (it is half-wavelength of 1.0 GHz incident wave in free space), the spectrum peak appears at about 0.8 GHz. The estimated length from the peak frequency is 18 cm. The estimated length is longer by 20 percent than the object length of 15 cm. In the cases of the 5 cm and 10 cm length, the similar results were obtained as shown in figure 4. The estimated length is in proportion to the estimated length from the spectrum of the resonance wave.

The polarization plane of the resonance wave is measured by rotation of the dipole antenna. By scanning the rotation angle of the receiver, the peak angle and amplitude at the resonance frequency are measured. The peak angle is a oscillation direction of the resonance wave. The peak amplitude shows the effective width of the oscillated current on the object surface. This polarization analysis of the resonance wave may be utilized for a two-dimensional reflectometer for metal or dielectric object.

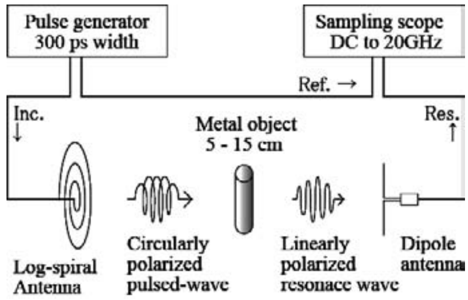

Fig. 1 A new pulsed-wave CT system design

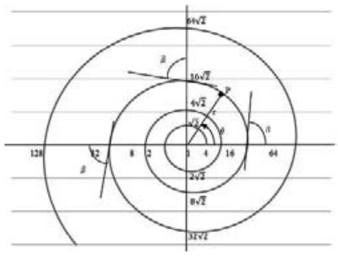

Fig.2 Antenna pattern of the log-spiral antenna

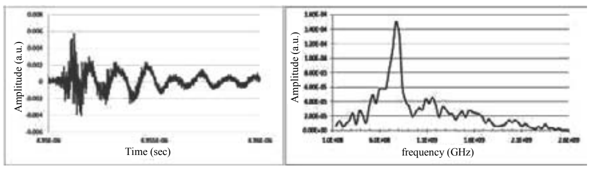

Fig. 3 The waveform and spectrum of the resonance wave in the case of the 15mm length of the metal rod.

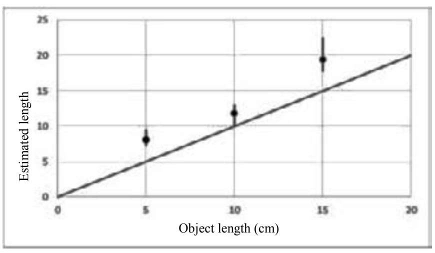

Fig. 4 The object length vs the estimated length

1) Mase, A. et al.: JINST **7** (2012) C01089.
2) B. Tobias. et al.: Plasma Fusion Res. **6** (2011) 2106042.
3) Nagayama, Y. et al.: J. Plasma Fus. Res. **87** (2011) 359.